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DEFENCE R&D DÉFENSE

Proposed Integration of VMSA Submarine for WIB

RPR FOM 2.0 Mapping and Data Agreements

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Canada

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Proposed Integration of VMSA Submarine for WIB

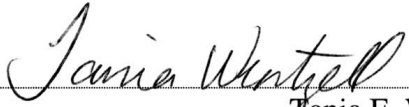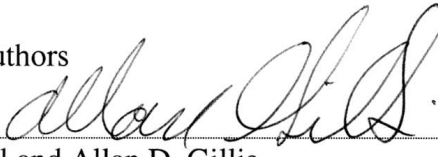*RPR FOM 2.0 Mapping and Data Agreements*

Tania E. Wentzell
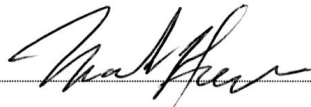Allan D. Gillis

Defence R&D Canada – Atlantic
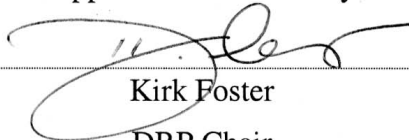
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Abstract

This paper describes the sensor and weapon models that will be used to simulate a red force submarine for the War-in-a-Box (WIB) exercise, as well as their configurable parameters and the necessary data agreements amongst all simulation components making up the WIB simulation. It proposes Virtual Maritime Systems Architecture (VMSA) and Real-Time Platform Reference (RPR) 2.0 Federation Object Model (FOM) objects and interactions that may be used to satisfy the communication requirements of the submarine simulation with other WIB federates. It is provided in response to a call for information from the WIB team; similar information has been requested from the other WIB participants. The resulting collection of information will be used to develop an overall RPR 2.0 FOM implementation plan and a set of data agreements for the exercise.

Résumé

Le présent document décrit les modèles de capteur et d'arme qui seront utilisés pour simuler un sous-marin de force rouge dans un exercice War-in-a-Box (WIB), ainsi que leurs paramètres configurables et les correspondances de données nécessaires entre tous les éléments qui prennent part à la simulation WIB. Il propose des objets et interactions du modèle objet de fédération (FOM) de l'architecture des systèmes virtuels maritimes (VMSA) et de la référence plate-forme en temps réel RPR 2.0, qui peuvent être utilisés pour satisfaire aux besoins de communications de la simulation de sous-marin avec d'autres fédérés WIB. Il est fourni en réponse à une demande d'information provenant de l'équipe WIB; des renseignements semblables ont également été demandés par d'autres participants à l'exercice WIB. La collecte résultante d'information permettra d'élaborer un plan global de mise en oeuvre FOM RPR 2.0 et un ensemble de correspondances de données pour l'exercice.

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Executive Summary

Report title

Wentzell, T.E. and Gillis, Allan; 2005; Proposed Integration of VMSA Submarine for WIB: RPR FOM 2.0 Mapping and Data Agreements; DRDC Atlantic TM 2005-273; Defence R&D Canada – Atlantic; Unclassified.

Background

Defence Research and Development Canada – Atlantic (DRDC Atlantic) is participating in a Canadian Forces-wide exercise called War-in-a-Box (WIB) which aims to connect military simulators and simulations (federates) located across the country using the High Level Architecture (HLA). The WIB team has chosen to use the Real-Time Platform Reference (RPR) Federation Object Model (FOM) version 2.0, draft 17 for the exercise.

The Virtual Combat Systems (VCS) Group is contributing a red force submarine to the exercise, simulated by a Virtual Maritime Systems Architecture (VMSA) federation with an object model that differs from that chosen for WIB. In order for the submarine to participate in the overall WIB federation, the data created and consumed by the VMSA simulation must be made meaningful to the rest of the participating federates, and vice versa.

A similar challenge exists for all federates. Documentation on an appropriate RPR 2.0 implementation for each federate was requested by the WIB team.

Principal results

This paper provides descriptions of the sensor and weapon models that will be used to simulate the enemy submarine and identifies configurable parameters and required data agreements. Most importantly, it proposes VMSA and RPR 2.0 FOM objects and interactions to be used to satisfy the communication requirements of the submarine with other WIB federates.

Significance of results

The information within this document is input into a much larger process. Without such information from each federate, it would not be possible to effectively achieve communication between them. Achieving this communication is a critical (probably the most critical) component of the WIB exercise.

Thinking beyond WIB, identification of a mapping (even on this limited scale) between the VMSA FOM which is heavily used by the VCS Group and the RPR 2.0 FOM which is a natural choice for simulators/simulations that are already DIS or RPR 1.0 – compliant, provides opportunity for the group to expand the capabilities of their virtual environment using existing, tried and true, military simulations.

Future work

The next step of the integration process for WIB is to review the inputs from each federate's responsible party and to collectively agree on how the RPR 2.0 FOM will be used to support the WIB exercise.

Sommaire

Titre du rapport

Wentzell, T.E. et Gillis, Allan; 2005; Proposed Integration of VMSA Submarine for WIB: RPR FOM 2.0 Mapping and Data Agreements (Intégration proposée de sous-marin VMSA pour WIB : mappage du FOM RPR 2.0 et correspondances de données); TM 2005-273 de RDDC Atlantique; R & D pour la défense Canada – Atlantique; non classifié.

Contexte

Recherche et Développement pour la défense Canada – Atlantique (RDDC Atlantique) participe à un exercice à l'échelle des Forces canadiennes appelé War-in-a-Box (WIB), qui vise à relier des simulateurs et des simulations militaires (fédérés) répartis à travers le pays au moyen d'une architecture de haut niveau (HLA). L'équipe WIB a décidé d'utiliser le modèle objet de fédération (FOM) de la référence plate-forme en temps réel RPR, version 2.0, ébauche 17, pour l'exercice.

Le Groupe des systèmes de combat virtuel (SCV) fournit un sous-marin de force rouge pour l'exercice, simulé par une fédération à architecture des systèmes virtuels maritimes (VMSA) que caractérise un modèle objet différent de celui choisi pour WIB. Afin que le sous-marin puisse s'intégrer à la fédération WIB d'ensemble, il importe que les données créées et utilisées par la simulation VMSA soient significatives pour le reste des fédérés participants, et vice versa.

Un défi semblable existe pour tous les fédérés. L'équipe WIB a demandé de la documentation sur une mise en oeuvre RPR 2.0 convenant à chaque fédéré.

Principaux résultats

Le présent document décrit les modèles de capteur et d'arme qui serviront à simuler le sous-marin ennemi et indique les paramètres configurables ainsi que les concordances de données requises. Mais, avant tout, il propose des objets et interactions de FOM VMSA et RPR 2.0 permettant de répondre aux besoins de communications du sous-marin avec d'autres fédérés WIB.

Portée des résultats

L'information incluse dans le document s'inscrit dans un processus beaucoup plus vaste. Sans l'information provenant de chacun des fédérés, il ne serait pas possible d'établir des communications efficaces entre eux. L'établissement de ces communications constitue un aspect crucial (c'est probablement celui qui revêt la plus grande importance) de l'exercice WIB.

Au-delà de WIB, la détermination (même à une échelle limitée) d'un mappage entre le FOM VMSA, qui est largement utilisé par le Groupe des SCV, et le FOM RPR 2.0, qui constitue un choix naturel pour les simulateurs/simulations déjà conformes à DIS ou à RPR 1.0, donne au

Groupe l'occasion d'élargir la capacité de l'environnement virtuel au moyen de simulations militaires existantes, mises à l'essai et ayant fait leurs preuves.

Recherches futures

La prochaine étape du processus d'intégration de WIB consiste à examiner la contribution du responsable de chaque fédéré et à s'entendre collectivement sur la façon dont le FOM RPR 2.0 sera utilisé à l'appui de l'exercice WIB.

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1. Background

1.1 War-in-a-Box

Defence Research and Development Canada – Atlantic (DRDC Atlantic) is participating in a Canadian Forces-wide exercise called War-in-a-Box (WIB). The aim of WIB is to connect military simulators and simulations which are located across the country using the High Level Architecture (HLA). Through a competitive bid process, the MÄK Run Time Infrastructure (RTI) was selected for this exercise. The Real-Time Platform Reference (RPR) Federation Object Model (FOM) version 2.0, draft 17 [1] was chosen by WIB team members to define the information and format of information that can be shared amongst the simulation federates. By mapping the internal data object models of each simulation into this format, the intention is that the models will become interoperable.

1.2 VCS Group's Simulation Environment

The Virtual Combat Systems (VCS) Group at DRDC Atlantic has been developing their HLA expertise over the past few years and has a collection of federates which can be used together to simulate elements of a maritime environment. These federates however, are based on the Virtual Maritime Systems Architecture (VMSA) [2], an application and extension of HLA inclusive of its own FOM, and are compiled against the Defense Modeling and Simulation Office (DMSO) RTI. VMSA takes a component-based approach to modelling a platform (e.g., typical federates are sonar, radar, motion), whereas as with RPR, modelling tends to be more at the platform level (e.g., typical federates are ship(s), sub(s), etc.).

1.3 VCS Group's Contribution to WIB

The VCS Group is contributing a red force submarine to the WIB exercise which will be simulated by a VMSA federation consisting of numerous federates (motion, helm, passive sonar, Target Motion Analysis (TMA), Electronic Support Measures (ESM), and Horizon Track Management Systems). A bridge is being developed [3] that will allow this federation to talk to the WIB RPR 2.0 federation. To all other WIB federates, this VMSA federation will appear simply as another federate, as it is through a single RPR 2.0 federate (a component of the bridge) that all communication will occur.

1.4 The Communication Challenge

Any federate that subscribes to data published by the submarine (VMSA federation) will receive that data. Similarly, the submarine requires particular data from the RPR 2.0 federation. For the most part, it is the data sharing between the VMSA federation and the Joint Semi-Automated Forces (JSAF) constructive simulation that is of interest. JSAF will be modelling the ships as well as Maritime Patrol Aircraft (MPA)

and helicopters. The data shared with other RPR 2.0 federates is expected to be a subset of the data shared with JSAF.

While at first this problem may not sound so complicated, it is important to realize how many levels of 'compatibility' have to exist in order to achieve effective communication, even between JSAF and VMSA. First of all, JSAF has its own 'JSAF' FOM that is used for communication between multiple copies of JSAF. This FOM must be mapped to the RPR 2.0 FOM via JSAF's 'Agile FOM Interface' (AFI) layer. Before even considering the FOM level, however, there is the issue of whether or not the element of interest is even part of both models. So, for any given requirement, the following questions must be answered:

- Does JSAF model it?
- Is it in the JSAF FOM?
- Is it in the RPR 2.0 FOM?
- Is it in the VMSA FOM?
- Is there a VMSA federate which models it?

Answering no to any of these questions has the potential to be a 'show-stopper', or at least to require creative work-arounds that take time to implement. When the answer to all questions is yes, then the challenge is to figure out how to take the representation of that element in each FOM and develop the mappings and conversions to move data from the JSAF model to the VMSA simulation (and vice versa) and, most importantly, have it mean the same thing to both sides.

In some cases, there may be multiple ways to represent something in the RPR 2.0 FOM. (This may also be true for the VMSA FOM, but since only developers at DRDC Atlantic are concerned with this, the choice is not of concern to other WIB members.) For example, in the RPR FOM AcousticSignatureIndex is an attribute of PhysicalEntity so it is possible to pass acoustic signatures and changes in them, via HLA. While this may make sense for some simulations, others (such as those being used in the VMSA federation) may have internal representations for the acoustic signatures of particular platforms, and therefore require the EntityType attribute of the BaseEntity object so that it can look up the appropriate signature. Both methods are legitimate applications of the RPR 2.0 FOM, but if the two methods are adopted by different federates in a federation, it will not function as intended.

Since the federates for WIB are from defence organizations across Canada, there is no single person that has knowledge of every federate. Thus, documentation on the RPR 2.0 implementation appropriate for each federate has been requested from the responsible parties. Once gathered, collective decisions can be made on the implementations that will be used for WIB.

1.5 About This Paper

This paper provides descriptions of the sensor and weapon models that will be used to simulate the enemy submarine and identifies configurable parameters and required data agreements. A brief discussion of damage modelling for VMSA is also included.

Most importantly, it proposes VMSA and RPR 2.0 FOM objects and interactions to be used to satisfy the communication requirements of the submarine with other WIB federates. Relevant object attributes and interaction parameters are included as well. Descriptions of such attributes and parameters are included in the tables and taken directly from [1] in the case of RPR 2.0 objects and interactions and from [2] for VMSA objects and interactions.

It should be noted that since the requirements of all federates will not be known until all such papers are completed, additions or modifications to this document may be made at a later time.

1.6   War-in-a-Box Set-Up

Figure 1 illustrates the anticipated set-up for WIB. It does not explicitly display all WIB federates, rather it highlights the ones of interest to this paper. A brief description of each federate is provided below.

The federates are:

- Passive Sonar – simulation of a passive sonar system for the detection of sound produced by other platforms. A signal follower is included for the creation of time-bearing tracks.

- ESM – simulation of an Electronic Support Measures (ESM) system for the detection of radar on other platforms and outputting time-bearing tracks.

- Horizon – a command and control / track management system that is used to display and manipulate sensor tracks, including those from the passive sonar and/or ESM federates. Horizon uses a VMSA plug-in to receive entity and track data from the VMSA federation, and its own communication protocol referred to as 'Promotion Comms' to promote tracks from one Horizon instance to another. It includes a plan view display, useful for operators involved with platform navigation, as well as an interface for launching torpedoes from the submarine.

- Sound – plays a sound file when weapons are launched or active sonar pings are received.

- JSAF – a constructive simulation environment for the creation of entities (e.g., platforms, humans) with weapons and sensors from all environments (with a focus on the maritime environment for WIB). Operators can assign a series of (override-able) tasks to each entity and they will be performed realistically, according to the built-in 'task frame intelligence'.

- Tacoma – a software bridge enabling meaningful data exchange between two systems. In the case of WIB, these systems are VMSA and RPR 2.0 federations and Tacoma consists of both federate and non-federate components. The 'on-ramps' are federates responsible for the direct

communication with their respective federations. The 'translators' turn FOM data into XML and XML data to FOM data. The 'spans' provide the actual means for communication between one federation and the other [3].
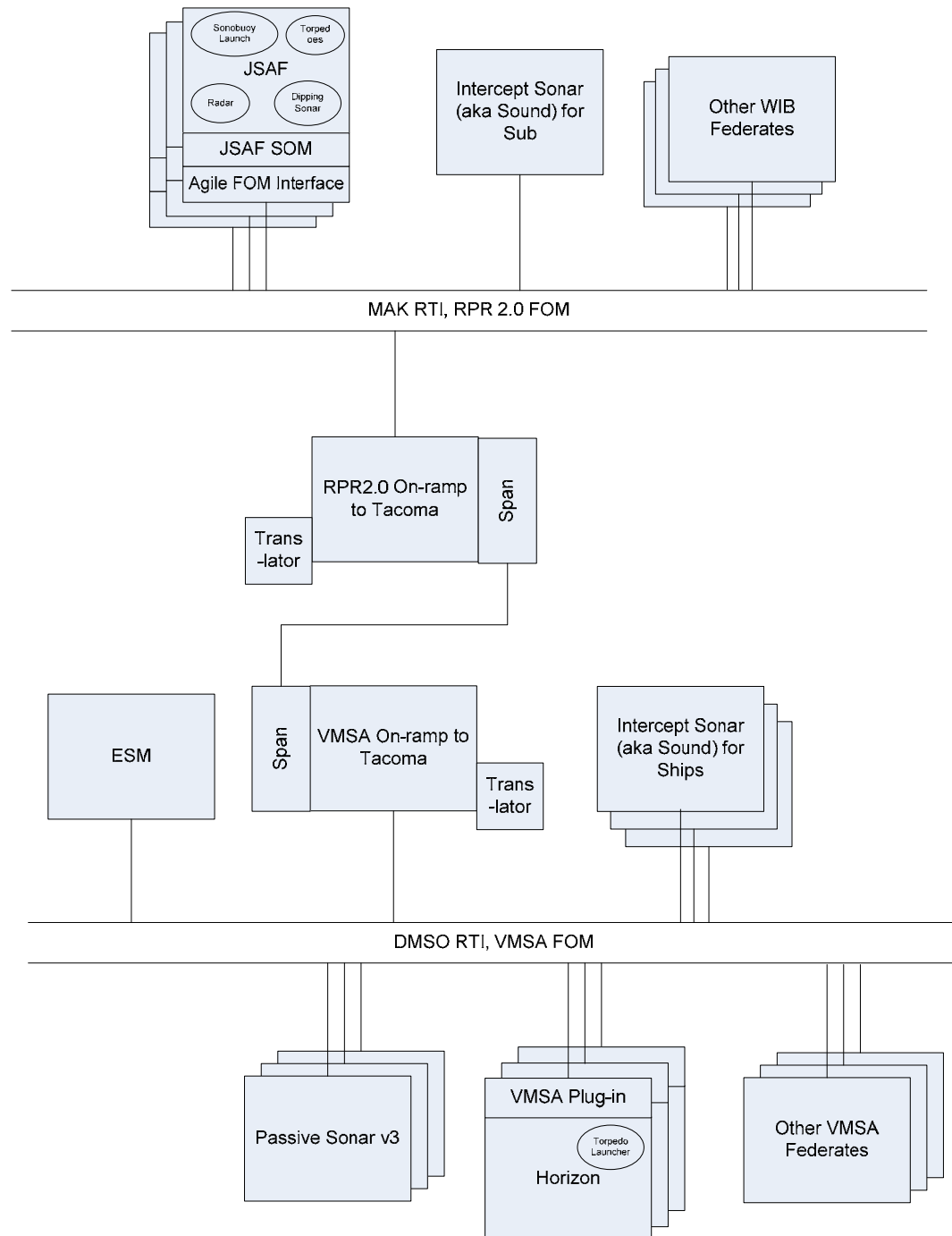

Figure 1. *Federates and Simulation Components Relevant to VMSA Submarine Integration*

2. Physical Entities

Many of the federates discussed in this paper require other federates to share information about the platforms they create and/or control. To prevent the repetition of this information throughout the paper, it is presented in this initial section and will be referred to when it is relevant to a particular federate.

2.1 VMSA Entities

In VMSA, composite entities are defined as entities that exist "in their own right". For example, ships, submarines, and aircraft are composite entities. Weapons such as missiles and torpedoes which are modelled individually are also included in this category.

Table 1. Composite Entity Attributes

OBJECT	ATTRIBUTE	DESCRIPTION
CompositeEntity	Name	Specifically identifies a particular instance of a CompositeEntity. Composed of a concatenation of terms, each of which conveys a well-defined characteristic of the entity.
	Description	Provides a user defined description of a CompositeEntity.
	Affiliation	Names the organisation the CompositeEntity is a member of.
	Role	Describes the role currently being executed by a CompositeEntity.
	Position	The position of a reference point of the CompositeEntity. The position is given with respect to the WGS84 Cartesian coordinate system.
	Velocity	The velocity of the CompositeEntity. The velocity components are given with respect to the WGS84 Cartesian coordinate system.
	Acceleration	The acceleration of the CompositeEntity. The components of the acceleration are given with respect to the WGS84 Cartesian coordinate system.
	Orientation	The orientation of a coordinate system fixed to the CompositeEntity with respect to the WGS84 Cartesian coordinate system. The origin of this coordinate system is given by the Position attribute.
	OrientationRate	The rate of change of the Euler angles that define the orientation of a coordinate system fixed to the CompositeEntity with respect to the WGS84 Cartesian coordinate system.
	DRAlgorithm	Specifies the algorithm used to dead reckon the kinematic attributes of the CompositeEntity.

The Affiliation attribute can take on one of three values as indicated in Table 2.

Table 2. Affiliation Attribute Values

AFFILIATION	DESCRIPTION
1	Blue
2	Red
3	Green

The DRAlgorithm attribute can take on one of eleven values. However, the dead reckoning algorithm currently used by all VMSA federates is DRAlgorithm = 11 which uses both velocity and acceleration to estimate current position and uses orientation rate to estimate current orientation. VMSA can also support the other (less accurate) dead reckoning algorithms listed in Section 4 of [4].

2.2 RPR 2.0 Entities

Similarly in RPR 2.0, physical entities include ships, submarines, missiles, torpedoes, etc..

Table 3. *Physical Entity Data Attributes*

OBJECT	ATTRIBUTE	DESCRIPTION
BaseEntity.PhysicalEntity	EntityIdentifier	Identifies the site, application, and entity of this object instance.
	EntityType	Kind, Country, Domain, Category, Subcategory, Specific, and Extra fields of the DIS Entity type.
	Spatial	Used to express the spatial relationship between the entity and the centre of the earth.
	ForceIdentifier	Enumeration distinguishing the different teams or sides in an exercise.

The ForceIdentifier attribute can take on one of four values are indicated in Table 4.

Table 4. *ForceIdentifier Attribute Values*

FORCE IDENTIFIER	DESCRIPTION
0	Other
1	Friendly
2	Opposing
3	Neutral

The Spatial variant record attribute includes six data elements to define the spatial information of an entity as shown in Table 5.

Table 5. *Spatial Variant Record Data Elements*

ATTRIBUTE	DATA ELEMENTS	DESCRIPTION
Spatial	AccelerationVector	The magnitude of the change in linear velocity of an object over time.
	AngularVelocityVector	The rate at which an entity's orientation is changing over time.
	DeadReckoningAlgorithm	Dead reckoning algorithm used by the issuing object.
	Orientation	The angles of rotation around the coordinate axes between the entity's attitude and the reference coordinate system axes (calculated as the Tait-Bryan Euler angles specifying the successive rotations needed to transform from the world coordinate system to the entity coordinate system).
	VelocityVector	The rate at which an entity's position is changing over time.
	WorldLocation	Location of the entity.

The DeadReckoningAlgorithm can take on one of nine values. DeadReckoningAlgorithm = 9 is equivalent to DRAlgorthim = 11 which is typically used in VMSA federates. (The Distributed Interactive Simulation (DIS) enumeration guide [4] refers to this algorithm as DRM(F,V,B). A description of these terms is (oddly) not provided in the DIS enumeration document, but can be found in [5].)

3. Submarine Sensors

This section describes the sensor models that will be used for the red submarine for the WIB exercise. As all of these sensors are of a passive nature, only data subscription requirements are relevant and discussed.

3.1 Passive Sonar

3.1.1 Model Description

The passive sonar federate was developed at DRDC Atlantic and uses basic sonar equations with some modifications to handle beam-forming. It can be configured as broadband and/or narrowband sonar. For each entity that should be detectable by the sonar instance, the acoustic signature of the platform is looked up in a target profile file internal to the model itself. This file may be defined very generally such that, for example, all warships have the same signature, or very specifically, such that a signature applies to only one specific platform. Transmission loss calculations use spherical and/or cylindrical spreading and absorption. Ambient noise calculations consider shipping level, rain state, and sea state. Alternatively, transmission loss and ambient noise can be input through data files. These inputs are used to develop beam maps which are then passed to a signal follower/tracker to identify tracks. The data output from this federate is therefore at the track level.

This model does not address the concept of the water surface or any medium besides water and therefore is not able to model the detection of aircraft. Thus, in it current form, only the detection of surface and subsurface entities are considered. Detection of air platforms will be considered in a future version of the sonar federate.

3.1.1.1 *Configurable Data*

The passive sonar federate provides four areas for configuration: environment, the sonar itself, the tracker, and the target profiles. Only the parameters most relevant to WIB are highlighted in this paper. The complete details are available in [6].

For the environment, average sound speed, ocean depth, shipping level (from 1(low) to 9 (high)), sea state (from 1(low) to 7 (high)), and rain state (NoRain, Intermediate, Moderate, Heavy) may be defined.

For the sonar, the frequency range for broadband operation is set by providing the central frequency for the band and the bandwidth. For narrowband operation, the minimum and

maximum frequency must be provided. A 'WatchSide' parameter is set to "Both" for a towed array or to "Port" or "Starboard" for flank arrays. In the case of a flank array, two sonar federates are run, one for each side. The position of the sonar system with respect to the host entity is currently not configurable. It is assumed to be located at the centre of the host entity.

For each target in the target profiles file, a name with at least one tone for narrow band detection and two tones for broadband detection are required. The tones for use by narrow band sonar have three attributes: central frequency, bandwidth, and signal level; for any frequency in the defined bandwidth, the signal level is as indicated. The tones used by broad band sonar have two attributes: frequency and signal level. The signal level for a particular frequency is determined by interpolating between the points defined in the file. There is a limitation here in that signal level is based solely on the type of platform and does not consider the state of the platform (e.g., its speed).

3.1.2 FOM Requirements

For this federate, only platform information for surface entities is required, as presented in Table 3 for the RPR 2.0 FOM. This information is mapped to composite entities in the VMSA FOM (Table 1) to which the VMSA passive sonar federate subscribes. (The sonar federate publishes sonar tracks to the VMSA federation, but these are not passed into the RPR 2.0 world and are thus not important to this document.)

3.1.3 Data Agreements

Appropriate and meaningful values for average sound speed, average ocean depth, shipping level, sea state, and rain state must be identified. Acoustic target profiles for every entity in the WIB scenario that could conceivably be detected by passive sonar (e.g., ships, submarines, torpedoes, etc.) must be defined. Sonobuoys modelled outside of VMSA will also need these target profiles so common data must exist for both models.

3.2 ESM

3.2.1 Model Description

The Electronic Support Measures (ESM) federate [7] was developed at DSTO and represents a generic ESM system which can be configured to reflect the characteristics of a particular type of system. It detects RF emissions of radar systems and then looks at the tasking information for that radar. The task defines the radar's mode which is looked up in a table along with the component name of the radar to obtain its operating configuration (e.g.,

frequency, effective radiated power (ERP), pulse width (PW), and pulse repetition frequency (PRF)). The radar emissions that can be detected by ESM must fall within the minimum and maximum ERP, PW, and PRF ranges specified for that ESM system. The elevation of the radar with respect to the ESM must also be within a predefined range. If these things do not hold, received power is 0. Otherwise, if radar is on, the range to the radar is calculated and it is determine whether there is line of sight to the radar and if the radar beam is in the direction of the ESM. If all of these are true, the signal power is calculated (considering antenna gains and losses, radiated power, wavelength and range) and is used to determine whether or not a detection is made. After a certain number of detections are made, a new track is started. As with the sonar federate, the outputs of this federate are time-bearing tracks.

3.2.1.1 *Configurable Data*

For each ESM system, configurable characteristics include maximum and minimum detection ranges for RF, PW, and PRF and antenna gain and losses. For each potential combination of a radar and task, frequency, ERP, PW, PRF are defined.

3.2.2 FOM Requirements

3.2.2.1 *VMSA*

Platform information for surface and air entities is required as shown in Table 1. In addition to this data, the radar and radar task information is required as described in Table 6. (The ESM federate publishes ESM tracks to the VMSA federation, but these are not passed into the RPR 2.0 world and are not important to this document.)

The Status attribute of the ComponentEntity object can take on one of four values as indicated in Table 7.

Table 6. *Relevant VMSA FOM Elements for ESM*

OBJECT	ATTRIBUTE	DESCRIPTION
ComponentEntity	ComponentName	This attribute provides a description of a ComponentEntity. This attribute is composed of a concatenation of terms, each of which conveys a well-defined characteristic of the entity.
	Status	Describes the status of a component entity.
	RelativePosition	The position of the ComponentEntity relative to the reference point of the parent CompositeEntity. The position is given with respect to the coordinate system fixed to the parent CompositeEntity.
	RelativeOrientation	The orientation of a coordinate system fixed to the ComponentEntity relative to the coordinate system fixed to the parent CompositeEntity.
	ParentCompositeEntity ObjectInstanceName	The object instance name of the CompositeEntity that is the parent of the ComponentEntity. This attribute is used to identify which CompositeEntity kinematic attributes should be used in conjunction with the RelativePosition and RelativeOrientation attributes to derive the kinematic attributes of the ComponentEntity.
SignalTask.ActiveTask.RFTask.RadarTask (S)	TaskName	Specifies a task performed by a system. This attribute is composed of a concatenation of terms, each of which conveys a well-defined characteristic of the task. A single system may perform any number of tasks.
	On	This is a boolean attribute which is True if the task is operable and False otherwise.
	RelativePosition	The position of the origin of the coordinate system associated with the signal task relative to the reference point of the parent CompositeEntity. The position is given with respect to the coordinate system fixed to the parent CompositeEntity.
	SignalPatternReference	Defines the coordinate system with respect to which the signal pattern is specified.
	SignalPatternOrientation	The orientation of a coordinate system fixed to the beam pattern, given with respect to the coordinate system specified by the SignalPatternReference attribute.
	SignalPatternOrientationRate	Depending on the dead-reckoning algorithm used, either the rate of change of the Euler angles that define the orientation of the signal pattern coordinate system (S) with respect to the reference coordinate system, or the angular velocity of the S coordinate system with respect to the reference coordinate system, with components of the angular velocity measured with respect to a stationary frame instantaneously coincident with the S frame.
	SignalPatternDRAlgorithm	The algorithm used to dead reckon the Euler angles that specify the orientation of the signal pattern associated with this task.
	ComponentObjectInstance Name	The object instance name of the ComponentEntity.SensorSystem that represents the sensor system that this task is associated with.
	ParentCompositeEntityObject InstanceName	The object instance name of the CompositeEntity that is the parent of the ComponentEntity that is responsible for generating the SignalTask.
	CentreFrequency	Centre or carrier frequency of the active signal task.
	RadarTask	Instances of this object class describe those tasks performed by a radar.

Table 7. *Status Attribute Values*

STATUS	DESCRIPTION
1	Standby
2	Active
3	Disabled
4	Silence

3.2.2.2   RPR 2.0

Platform information for surface and air entities is required as shown in Table 3. In addition to this data, the radar (emitter system) and beam information is required as described in Table 8.

Table 8. *Relevant RPR 2.0 FOM Elements for ESM*

OBJECT	ATTRIBUTE	DESCRIPTION
EmbeddedSystem.EmitterSystem (S)	HostObjectIdentifier	Object instance ID of the host to which the object instance is attached.
	RelativePosition	Location of the embedded system relative to the host's position.
	EntityIdentifier	Identifies the site, application, and entity number of the host to which the object instance is attached.
	EmitterIndex	Specifies the identification number for each emitter system on a given host.
	EmitterFunctionCode	Specifies the function for a particular emitter as an enumeration.
	EmitterType	EmitterType specified as an enumeration.
EmitterBeam	BeamParameterIndex	This attribute specifies a beam parameter index number that shall be used by receiving entities in conjunction with the emitter name attribute (EmitterSystem object class) to provide a pointer to the stored database parameters required to regenerate the beam.
	BeamAzimuthCenter	This attribute specifies the azimuth centre angle of the beam's scan volume relative to the emitter system. This attribute in conjunction with BeamElevationCenter, BeamAzimuthSweep, and BeamElevationSweep describes the scan volume covered by the emitter beam scan.
	BeamAzimuthSweep	This attribute specifies the azimuth sweep of the beam's scan-volume relative to the azimuth centre. This attribute in conjunction with BeamAzimuthCenter, BeamElevationCenter, and BeamElevationSweep describes the scan volume covered by the emitter beam scan.
	BeamElevationCenter	This attribute specifies the elevation centre angle of the beam's scan-volume relative to the emitter system. This attribute in conjunction with BeamAzimuthCenter, BeamAzimuthSweep, and BeamElevationSweep describes the scan volume covered by the emitter beam scan.
	BeamElevationSweep	This attribute specifies the elevation sweep of the beam's scan volume relative to the BeamElevationCenter. This attribute in conjunction with BeamAzimuthCenter, BeamAzimuthSweep and BeamElevationCenter describes the scan volume covered by the emitter beam scan.
	BeamFunctionCode	This enumerated attribute specifies the beam's function. It serves as a general data filter.
	BeamIdentifier	This attribute specifies a unique database number assigned to differentiate between otherwise similar or identical emitter beams within an emitter system.
	EffectiveRadiatedPower	This attribute specifies the EffectiveRadiatedPower for the emission in dBm. For a radar or a noise jammer, this attribute shall indicate the peak of the transmitted power. Thus, it includes peak transmitter power, transmission line losses, and peak of the antenna gain.
	EmissionFrequency	This attribute specifies the frequency of the emission in hertz. Frequency modulation for a particular emitter and mode shall be derived from database parameters by the reflecting federate.
	EmitterSystemIdentifier	This attribute specifies a reference to the emitter system object from which the beam is emanating.
	EventIdentifier	Used by the generating federate to associate EmitterSystem and EmitterBeam changes.
	FrequencyRange	This attribute specifies the bandwidth of the frequencies corresponding to the Frequency attribute. Thus, if, for operational purposes, the Frequency is supposed to be a single number, then the Frequency Range shall be zero
	PulseRepetitionFrequency	This attribute specifies the average PulseRepetitionFrequency of the emission in hertz. PulseRepetitionFrequency modulation for a particular emitter and mode shall be derived from database parameters by the reflecting federate.
	PulseWidth	This attribute specifies the average pulse width of the emission in microseconds. Pulse modulation for a particular emitter and mode shall be derived from database parameters by the reflecting federate.
	SweepSynch	This attribute is provided to allow a receiver to synchronize its regenerated scan pattern to that of the emitter. This attribute when employed specifies the percentage of time a scan is through its pattern from its origin. The pattern and origin data are derived from database parameters.

The enumeration list for the EmitterFunctionCode attribute of the EmitterSystem can be found in [4]; there are 97 entries and thus they are not all listed here. The codes represent functions such as ranging, tracking, and navigation.

The BeamFunctionCode attribute of the EmitterBeam object can take on one of 17 values as indicated in Table 9.

3.2.3 Data Agreements

RF emissions for each ship or air radar in the WIB scenario that could conceivably be detected by ESM must be defined.

***Table 9**. BeamFunctionCode Attribute Values*

STATUS	DESCRIPTION
1	Search
2	Height finder
3	Acquisition
4	Tracking
5	Acquisition and tracking
6	Command guidance
7	Illumination
8	Range only radar
9	Missile beacon
10	Missile fuze
11	Active radar missile seeker
12	Jammer
13	IFF
14	Navigational / Weather
15	Meteorological
16	Data transmission
17	Navigational directional beacon

3.3 "Intercept" Sonar

This federate is being developed at DRDC Atlantic to fill a requirement for the WIB submarine to have an ability to detect enemy torpedo launches and dipping sonar pings, and is more commonly referred to as the 'sound federate'. These sounds would not be detected by the passive sonar model that is being used; rather they would be ignored by the tracker due to their transient nature. (The torpedo itself, however, as it moves through the water towards its target, may be detected by the passive sonar model. The sound federate is only concerned with the launch.)

In an effort to provide a limited detection capability quickly, a federate is being created which simply subscribes to specific objects and interactions and plays a corresponding sound when there is a match. For example, when a torpedo is

launched, the sound of a torpedo being launched will be played. At this point, directional information is not being provided and there is no consideration for which platform is producing the sound, but these are desired enhancements.

For WIB, the submarine is only concerned with torpedoes and pings originating in the RPR 2.0 federation. For this reason, the federate needs to be compiled as a RPR 2.0 federate and subscribe to RPR 2.0 objects and/or interactions. (Making it a RPR 2.0 federate prevents the bridge from needing to translate data between the two federations.) This federate will be run in the red submarine simulation room during the WIB exercise and will only be heard by the 'crew' of the red submarine.

3.3.1 FOM Requirements

The RPR 2.0 interaction and object that may be used to indicate torpedo launching and sonar pinging are shown in Table 10.

Table 10. *Relevant RPR 2.0 FOM Elements for Sound*

OBJECT/INTERACTION	ATTRIBUTE	DESCRIPTION
EmbeddedSytem.UnderwaterAcoustics. ActiveSonar (S)	FunctionCode	Indicates the main purpose of the active sonar.
WeaponFire (S)	MunitionType	The type of munition being fired.

Table 1 describes the possible values of the FunctionCode attribute.

Table 11. *Relevant RPR 2.0 FOM Elements for Sound*

FUNCTION CODE	DESCRIPTION
0	Other
1	Platform search/detect/track
2	Navigation
3	Mine Hunting
4	Weapon search/detect/track/detect

The sound federate will play a sonar ping sound file whenever the function code is set to 1 (Platform search/detect/track). The file will be replayed at a fixed interval until the function code changes.

Similarly, it will play a torpedo launch sound file whenever the WeaponFire interaction is published and the MunitionType is appropriate for attacking a submarine. (This prevents the sound from playing when the ship launches a missile at a hostile air platform.)

3.3.1.1 *Configurable Data*

The sound files that will be used by the federate can be set in the configuration file.

3.3.2 Data Agreements

This federate needs to know all possible weapon types that could be launched at the submarine.

4.   Submarine Torpedoes

This section considers the HLA communication required between the VMSA simulation of the red submarine and the RPR 2.0 federate, JSAF, in order to fully model red force torpedoes.

4.1   Torpedoes

The red submarine needs the capability of launching torpedoes at the blue ships. As this was not an existing capability, it was decided that the decision to launch the torpedo would be made by an operator on the red sub (simulated by the VMSA federation), but the actual creation, launch and control of the torpedo would be the responsibility of JSAF in the RPR 2.0 federation. Within the Horizon Command and Control (C2) software, a plug-in was developed to set the torpedo's launch criteria, including the type of torpedo, the launch bearing and the range at which to turn on the torpedo's acoustic sensing system. Torpedoes are launched one at a time, but may be launched in quick succession if desired. While JSAF controls the torpedo entity, its position will be mirrored in the Horizon plan view display.

4.1.1   FOM Requirements

4.1.1.1   VMSA

The VMSA Launch interaction is required and is described in Table 12.

Table 12.   *Relevant VMSA FOM Elements for Torpedo Launching*

INTERACTION	PARAMETERS	DESCRIPTION
ControlMessage. LaunchControl. Launch (P)	InitiatorObject InstanceName	Identifies the object instance that has initiated the interaction.
	ControlMessageID	Provides an identifier of this message that is unique to the sender. (1, 2, 3, ...).
	Plan	The details of the launch plan. The format for this plan is agreed to by the initiating and receiving federates during federation design (XML format)
	EntityName	The name of the entity to launch. (This is left blank since the name is expected to be assigned by JSAF).

The Plan parameter's format is not explicitly defined by the FOM. It is up to the scenario developers to define the details of this parameter. For the purposes of WIB it has been defined as shown in Table 13.

Table 13. *Relevant Elements of Launch Interaction's Plan Parameter*

DATA ELEMENT	MEANING
WeaponType	The type of weapon being launched.
LaunchBearing	The bearing at which to launch the torpedo, relative to the platform launching the torpedo.
WeaponActiveRange	Range at which to turn on acoustic homing.

The torpedo itself is modelled in JSAF and displayed in Horizon. In VMSA, a torpedo is modelled as a CompositeEntity .SubSurface entity. The attributes for this entity were shown in Table 1.

4.1.1.2 RPR 2.0

The VMSA launch interaction is translated into a RPR 2.0 WeaponFire interaction by the bridge. The WeaponFire interaction is as shown in Table 14.

Table 14. *Relevant RPR 2.0 FOM Elements for Torpedo Launching*

ATTRIBUTE	ATTRIBUTE	DESCRIPTION
WeaponFire	EventIdentifier	An ID generated by the issuing federate used to associate related fire and detonation events.
	FireControlSolution Range	The range used in the fire control solution. Zero if the range is unknown or inapplicable.
	FireMissionIndex	A unique index to identify the fire mission (used to associate weapon fire interactions in a single fire mission).
	FiringLocation	The location in the world coordinate system of the weapon fire.
	FiringObjectIdentifier	The ID of the object firing the munition.
	FuseType	The type of fuse on the munition.
	InitialVelocityVector	The velocity vector of the munition when fired.
	MunitionObject Identifier	The ID of the associated munition object (if any).
	MunitionType	The type of munition being fired.
	QuantityFired	The number of rounds fired in the fire event.
	RateOfFire	The rate of fire at which the munitions in the burst described in the fire event.
	TargetObjectIdentifier	The ID of the object being fired at (if any).
	WarheadType	The type of warhead fitted to the munition being fired.

Since torpedoes will only be launched from the sub one at a time, there will be a separate WeaponFire interaction associated with each torpedo launch. Therefore, QuantityFired is always '1' and RateOfFire is always '1'. Also, the torpedo destination is determined by the launch bearing and sensor activation range, so TargetObjectIdentifier will always be blank.

The torpedoes created by JSAF are expected to be published as BaseEntity.PhysicalEntity.Munition entities in RPR 2.0 which will be translated into CompositeEntity.SubSurface entities in

VMSA. The BaseEntity.PhysicalEntity.Munition entity attributes were shown in Table 3.

5.   Damage Modelling

Details of the damage modelling capabilities of all WIB federates were also requested by the WIB technical team. However, VMSA currently does not model damage. Prior to WIB, the VCS Group did not have a method to launch weapons using their core VMSA federates so damage modelling had not come up as a requirement. Therefore, the submarine (VMSA simulation) is expecting JSAF to handle its damage modelling. This includes informing the submarine operators when the sub has been hit, and when the sub has successfully destroyed any blue entities that it launches its torpedoes at.

The Canadian Forces Maritime Warfare Center (CFMWC) is preparing a description of JSAF's capabilities and requirements in terms of its WIB application, similar to this one for the VMSA simulation. Once this information is available, a better understanding of JSAF's damage modelling is expected. Until this time, there are a few foreseeable implementations:

- The damage modelling will all be handled through RTI calls and not involve FOM objects or interactions at all,

- JSAF will indicate catastrophic damage by sending a 'remove entity' type of interaction, or

- Damage information will simply be radioed from one room to the other and the JSAF and/or VMSA operator(s) will manually remove the entity that has been destroyed. A nicety of this method is that the scenario controllers could alternatively radio 'passive sonar system down', 'ESM down', 'Helm control down' etc. and this could be simulated by turning off the relevant displays.

Further investigation must clearly occur on this topic.

6. Blue Force Sensors

This section considers the possible methods by which the red submarine or its weapons may be detected. In order to enable a 'fair fight', the sub must somehow announce to other entities that it is raising its ESM antenna, periscope, or snorkel or launching a torpedo.

6.1 Radar

When the submarine raises its ESM antenna, periscope, or snorkel, its radar cross section (RCS) changes. In VMSA, RCS is currently dependent only on the type of platform being modelled and its relative position to the radar, so 'changing' the RCS is an unknown concept. Similarly, in JSAF, the RCS calculation accounts for the type of platform (which is looked up in a table) and its location and orientation. Also, looking through some of the JSAF code (since the details of JSAF models are not well-documented), the concept of 'PeriscopeUp' exists, suggesting that its radar model does somehow account for this as well. While the RPR 2.0 FOM provides the opportunity to publish RCS for all entities, this does not fit well with either the VMSA or JSAF modelling concepts. Reading through the RPR 2.0 documentation [1] and in particular the DIS enumeration document [4], the most fitting way to model the change in RCS is by considering the periscope, snorkel and ESM antenna as 'articulated parts' of the submarine; that is, modelling the physical changes that result in an RCS change.

It should be noted that the VMSA does not currently model periscopes, antennas, or snorkels at all. This is something the VCS Group must find a 'quick fix' for prior to WIB. It is important however to have agreement amongst WIB members on how these things will be captured in the RPR 2.0 FOM as it effects how such a fix will be realized.

The proposed RPR 2.0 mapping for these components is described in the following FOM section.

6.1.1 FOM Requirements

Since a single physical entity can have more than one articulated part, such parts are represented by an array, as indicated in Table 15. In addition, the platform information for subsurface entities is required, as presented in Table 3.

Table 15.   *Relevant RPR 2.0 FOM Elements for Radar Detection of Sub*

OBJECT	ATTRIBUTE	DESCRIPTION
BaseEntity.PhysicalEntity. Platform.SubmersibleVessel	ArticulatedParametersArray	Identification of the visible parts, and their states, of the entity which are capable of independent motion.

Referring to [8], the fields of the ArticulatedParametersArray are found to be:

Table 16.   *Fields of the ArticulatedParametersArray Attribute*

ATTRIBUTE	FIELDS	
ArticulatedParametersArray	# Articulation Parameters	
	Parameter Type Designator *	* these are repeated for each articulated part
	ID-Part Attached To *	
	Parameter Type *	
	Parameter Value *	

Note that the 'Change Indicator' field has not been included as this is assumed to be a DIS concept, rather than HLA. Referring to [4], the 'Parameter Type Designator' field can take on two values: 0 for Articulated Parts and 1 for Attached Parts. The periscope, snorkel and ESM antenna are all articulated parts and therefore the value of this field will be 0 for each entry in the array.

The 'ID-Part Attached To' field will always have a value of 0 since these parts are each attached directly to the sub, rather than to another articulated part.

The 'Parameter Type' field uses integer values to indicate both the kind of part (e.g., periscope) and the parameter of interest (e.g., position). The following indexes are found in [4]:

Table 17.   *Articulated Part Indices*

INDEX (x)	ARTICULATED PART
2048	Periscope
2080	Generic Antenna
2112	Snorkel

The following offsets from these indices are used to indicate the parameter of interest. (Only relevant offsets are shown here.)

Table 18.   *Articulated Part Parameter Offsets*

OFFSET	PARAMETER
x + 1	Position
x + 3	Extension
x + 4	Extension Rate

For example, for the position of the periscope, the 'Parameter Type' field's value would be 2049.

Finally, the 'Parameter Value' field is the actual information. For example, for 'Parameter Type' 2049, the 'Parameter Value' would be the position of the periscope in World Coordinates.

6.1.2 Data Agreements

All federates modelling radar with look-up tables should have comparable RCS values for each entity in a given state (e.g., periscope up).

6.2 Passive Sonar

The passive sonar that will be used on the frigates is the same as the model that is used for the submarine. While the ships will be controlled by JSAF within the RPR 2.0 federation, their passive sonar is modelled fully within VMSA. This means that JSAF entities will not automatically react to passive acoustic information, and it will be up to the JSAF operators to decide if action (e.g., course change) needs to be taken based on information in the passive sonar (Horizon) display. For details of the model, the HLA implementation, and the configurable parameters, refer back to Section 3.1.

6.3 Dipping Sonar, Active Sonar and Sonobuoys

It is expected that the entity data in Table 1 (for VMSA) and Table 3 (for RPR 2.0) will be sufficient for the dipping and active sonar as well as the sonobuoys. VMSA entities do not currently publish Target or Acoustic Signatures. Rather, models that would be interested in these signatures contain internal tables mapping the platform's type to a signature. The authors suspect a similar implementation in JSAF, which will be confirmed upon receipt of the JSAF implementation document.

6.3.1 Data Agreements

Since JSAF is modelling passive acoustics for sonobuoys and VMSA is modelling passive sonar for ships and the submarine, it is important for both VMSA and JSAF to have the same acoustic signatures in their tables. This is not an issue for the dipping sonar since all active acoustics are within JSAF.

6.4 "Intercept" Sonar

This federate is the same federate described in Section 3.3, however, in this case it will be configured as a VMSA federate and subscribe to a single VMSA interaction which will indicate the launch of a torpedo. The only VMSA Launch interactions that will exist in the WIB scenario will be a result of the submarine launching a torpedo at a blue ship. Thus, unlike with the RPR 2.0 version, there is no value to filtering the interactions based on their weapon type. It will not be clear to the blue ships which

ship is being attacked or from what direction; just that attack is underway and to 'be warned'.

6.4.1 FOM Requirements

The sound federate will play a torpedo launch sound when the VMSA ControlMessage.LaunchControl.Launch is received. The parameters of the interaction are not relevant to this federate.

7. Overall FOM Requirements

7.1 VMSA FOM Subset

Table 19 summarizes the relevant VMSA FOM requirements for WIB. The publish (P) and subscribe (S) indicators are from the point of view of the VMSA side of the bridge (Tacoma VMSA On-ramp).

Table 19. *VMSA FOM Requirements – Summarized*

OBJECT	ATTRIBUTE
CompositeEntity.Subsurface (P) CompositeEntity.Surface (S) CompositeEntity.Air (S)	Name
	Description
	Affiliation
	Role
	Position
	Velocity
	Acceleration
	Orientation
	OrientationRate
	DRAlgorithm
ComponentEntity (S)	ComponentName
	Status
	RelativePosition
	RelativeOrientation
	ParentCompositeEntity
	ObjectInstanceName
SignalTask.ActiveTask.RFTask.RadarTask (S)	TaskName
	On
	RelativePosition
	SignalPatternReference
	SignalPatternOrientation
	SignalPatternOrientationRate
	SignalPatternDRAlgorithm
	ComponentObjectInstance Name
	ParentCompositeEntityObjectInstanceName
	CentreFrequency
	RadarTask
ControlMessage.LaunchControl.Launch (PS)	InitiatorObjectInstanceName
	ControlMessageID
	Plan
	EntityName

7.2 RPR 2.0 FOM Subset

Table 20 summarizes the relevant RPR 2.0 FOM requirements for WIB. The publish (P) and subscribe (S) indicators are from the point of view of the RPR 2.0 side of the bridge (Tacoma RPR 2.0 on-ramp).

Table 20. *RPR 2.0 FOM Requirements – Summarized*

OBJECT	ATTRIBUTE
BaseEntity.PhysicalEntity.Platform.Aircraft (P), BaseEntity.PhysicalEntity.Platform.SurfaceVessel (P), BaseEntity.PhysicalEntity.Munition (P)	EntityIdentifier
	EntityType
	Spatial
	ForceIdentifier
BaseEntity.PhysicalEntity.Platform.SubmersibleVessel (S)	EntityIdentifier
	EntityType
	Spatial
	ForceIdentifier
	ArticulatedParametersArray
EmbeddedSystem.EmitterSystem (P)	HostObjectIdentifier
	RelativePosition
	EntityIdentifier
	EmitterIndex
	EmitterFunctionCode
	EmitterType
EmitterBeam (P)	BeamParameterIndex
	BeamAzimuthCenter
	BeamAzimuthSweep
	BeamElevationCenter
	BeamElevationSweep
	BeamFunctionCode
	BeamIdentifier
	EffectiveRadiatedPower
	EmissionFrequency
	EmitterSystemIdentifier
	EventIdentifier
	FrequencyRange
	PulseRepetitionFrequency
	PulseWidth
	SweepSynch
EmbeddedSytem.UnderwaterAcoustics.ActiveSonar (P)	FunctionCode
WeaponFire (PS)	EventIdentifier
	FireControlSolutionRange
	FireMissionIndex
	FiringLocation
	FiringObjectIdentifier
	FuseType
	InitialVelocityVector
	MunitionObjectIdentifier
	MunitionType
	QuantityFired
	RateOfFire
	TargetObjectIdentifier
	WarheadType

8. The Next Step

The next step of the integration process for WIB is to review the inputs from each federate's responsible party and to collectively agree on how the RPR 2.0 FOM will be used to support the WIB exercise. Ideally, the RPR 2.0 implementation of each federate can be realized without significant modifications to the individual proposed plans. In designing this plan for the VMSA simulation, the RPR 2.0 documentation [1] was closely followed and considered to minimize potential conflicts with other federates.

Since the initial integration testing for federates is scheduled to occur next month (January 2006), development of federates, bridges, and other software interfaces has been forced to begin (and in some cases end) without *a priori* knowledge of how the RPR 2.0 FOM will be applied to WIB or what data agreements will be required. This means that following such decisions, the development that has already occurred may require re-examination. Clearly this is not an ideal situation, but given the restrictive timelines, there was no suitable alternative. However, even with the quickly approaching deadlines, the VCS Group remains confident in their ability to deliver a VMSA-simulated submarine with passive sonar and ESM sensors and a torpedo launching capability that will interact appropriately with JSAF in a RPR 2.0 federation. It is hoped that other responsible parties have similar confidence in providing their own federate(s) and that in the end a country-wide distributed simulation capability will be demonstrated and exercised.

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List of symbols/abbreviations/acronyms/initialisms

AFI	Agile FOM Interface
C2	Command and Control
CFMWC	Canadian Forces Maritime Warfare Center
DIS	Distributed interactive Simulation
DMSO	Defense Modeling and Simulation Office
ERP	Effective Radiated Power
ESM	Electronic Support Measures
FOM	Federation Object Model
HLA	High Level Architecture
JSAF	Joint Semi-Automated Forces
MPA	Maritime Patrol Aircraft
PRF	Pulse Repetition Frequency
PW	Pulse Width
RCS	Radar Cross Section
RPR	Real-time Platform Reference
RTI	Run Time Infrastructure
TMA	Target Motion Analysis
VCS	Virtual Combat System
VMSA	Virtual Maritime Systems Architecture
WIB	War-in-a-Box

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This paper describes the sensor and weapon models that will be used to simulate a red force submarine for the War-in-a-Box (WIB) exercise, as well as their configurable parameters and the necessary data agreements amongst all simulation components making up the WIB simulation. It proposes Virtual Maritime Systems Architecture (VMSA) and Real-Time Platform Reference (RPR) 2.0 Federation Object Model (FOM) objects and interactions that may be used to satisfy the communication requirements of the submarine simulation with other WIB federates. It is provided in response to a call for information from the WIB team; similar information has been requested from the other WIB participants. The resulting collection of information will be used to develop an overall RPR 2.0 FOM implementation plan and a set of data agreements for the exercise.

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